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ABSTRACT

This first in a series of eight modules for a course titled Mechanical Inspection describes the type of pumps used in nuclear power plant systems, the basic operating principles of each type, and the inspection activities performed by the quality assurance/quality control technician. The module follows a typical format that includes the following sections: (1) introduction, (2) module prerequisites, (3) objectives, (4) notes to instructor/student, (5) subject matter, (6) materials needed, (7) procedures, (8) data table, (9) reference materials, (10) test. (The course is one of fifteen technical courses for the second year of a two-year postsecondary curriculum in Nuclear Quality Assurance/Quality Control Technology.) (LRA)

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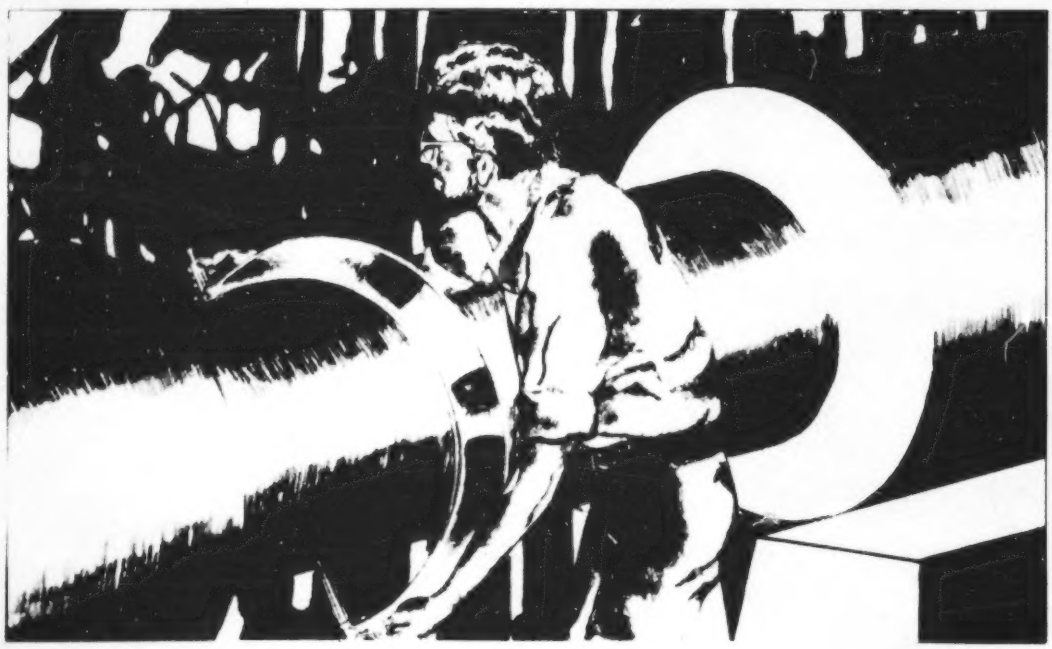
NUCLEAR TECHNOLOGY

COURSE 30 MECHANICAL INSPECTION

MODULE 30-1 Pump Inspection



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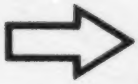
GENERAL PHYSICS CORPORATION
Columbia , Maryland

COURSE MODULES

COURSE 30 MECHANICAL INSPECTION



Module 30-1 Pump Inspection
Module 30-2 Pump Functional Testing
Module 30-3 Valve Inspection
Module 30-4 Piping Inspection
Module 30-5 Surface Cleaning Inspection
Module 30-6 Protective Coating Inspection
Module 30-7 Pressure Vessel Inspection
Module 30-8 Rotating Equipment Inspection

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This module was prepared for General Physics Corporation by Ed Wasil and John Espy, General Physics Corporation.

GENERAL PHYSICS CORPORATION

1979

INTRODUCTION

The Nuclear QA/QC Technician typically performs inspection of pump installation activities in accordance with written procedures. These inspections consist of observing work practices, visually inspecting pumps and surroundings, and reviewing records. The objective of these inspections is to verify that the correct pump is properly installed in the right location. This module describes these inspection activities.

Prior to describing inspection activities, this module describes the types of pumps used in the nuclear power plant systems and the basic operating principles of each type. This fundamental description of technical features of pumps should assist the student/trainee in visualizing the application of inspection activities.

Inspection activities are described for the period of time from release of a pump from stores until the time of functionally testing the pump after installation. These inspections are divided into three phases consisting of preinstallation inspections, installation inspection, and preoperational integrity tests. It is noted that Module 30-2 of Course 30 describes preoperational functional testing of components.

MODULE PREREQUISITES

It is suggested that the student/trainee complete Course 15, Metallurgy and Metal Properties prior to beginning this course.

OBJECTIVES

Upon completion of this module, the student/trainee can:

1. Describe the fundamental operating principles associated with centrifugal, jet, and displacement pumps.
2. Define:
   a. static suction lift
   b. static suction head
   c. discharge head
   d. total static head
3. Describe how dynamic heads differ from static heads with respect to suction, discharge, and pump heads.
4. State the purpose of preinstallation inspection.
5. Describe the preinstallation inspections associated with identification, processes and procedures, pump physical conditions, and site conditions.
6. State the purpose of installation inspections.
7. Describe the installation inspections associated with control of procedures and processes, nondestructive examinations, work in progress, and final installation.
8. Briefly describe how to conduct a shaft seal/leakage test.
9. Briefly describe how to conduct a hydrostatic test.

FUNDAMENTAL PUMP DESIGNS

Classification of Pumps

Pumps may be classified on the basis of their applications, the materials from which they are constructed, or the fluids which they handle. In all of these classifications, however, is a more basic classification which is based on the principles of operation of the pumps. Every pump imparts energy to the fluid it handles and the principles by which this energy is added to the fluid provides a basis of pump classification which has universal meaning regardless of any additional classification. These principles provide for classifications of pumps into two categories: dynamic and displacement as illustrated in Figure 30-1-1.

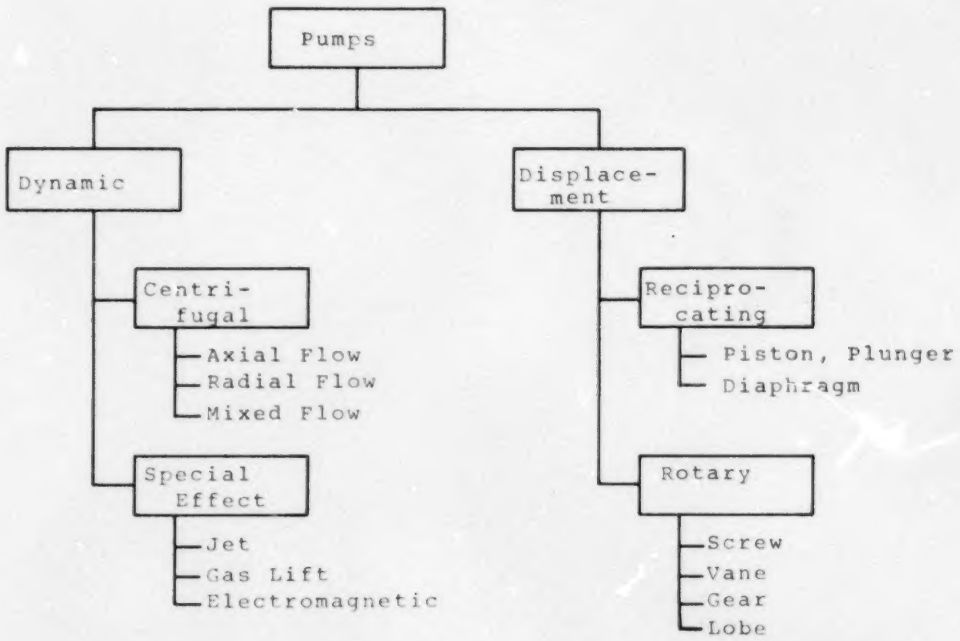

Figure 30-1-1. Classification of Pumps

Dynamic pumps continuously add energy to increase fluid velocity within the pump such that subsequent velocity reduction within or beyond the pump produces a pressure increase. Dynamic pumps are comprised of centrifugal pumps and special effect pumps such as jet pumps and electromagnetic pumps.

Displacement pumps periodically add energy by physically moving an enclosed volume of fluid which results in a pressure increase up to a value required to move that volume into the discharge line. Displacement pumps are comprised of reciprocating and rotary pumps.

Water Height Versus Pressure

A direct correlation exists between the height of a column of water and the pressure at the base of the column due to the force of gravity. At the standard temperature of 68°F, this correlation is 100 pounds per square inch (psi) for each 231 feet of water as illustrated in Figure 30-1-2. It is noted that the relationship is valid whether measuring the force of an existing column of water or calculating the height that a column of water would achieve if a known pressure were applied at the base of the column.

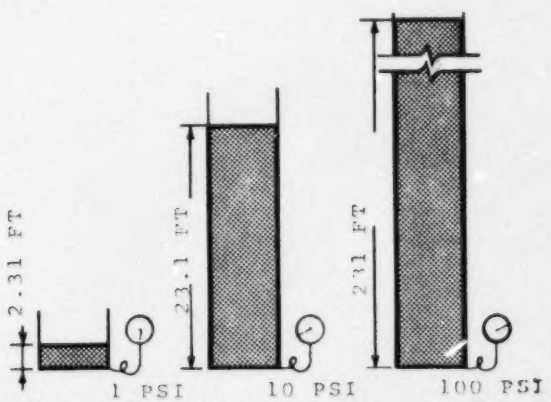

Figure 30-1-2. Effect of water height on pressure

Suction Lift and Suction Head

Design of a pump permits its use at a placement above or below the level of fluid supply. Pumps which operate at a placement above the level of fluid supply must be capable of lifting the fluid to the axis of the pump. This distance in feet is termed static suction lift and is illustrated in Figure 30-1-3

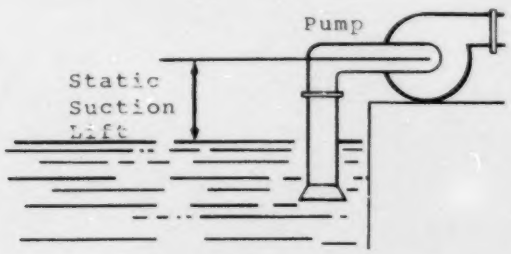

Figure 30-1-3. Static suction lift.

Pumps which operate at a placement below the level of fluid supply have a pressure at their suction which is generated by the height of fluid above the axis of the pump. This height of fluid in feet is termed static suction head and is illustrated in Figure 30-1-4.

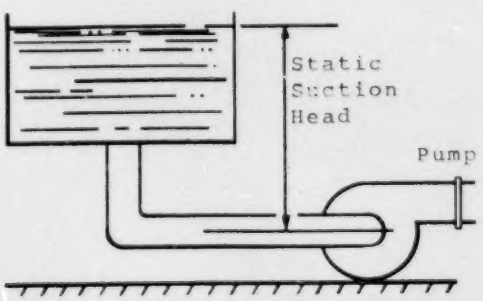

Figure 30-1-4. Static suction head.

When a pump is operating, the static suction lift and

static suction head are not directly sensed by the pump. This is because the fluid is flowing at some velocity and because there are frictional losses in the line. An operating pump located above the supply of fluid must be capable of a total dynamic suction lift equal to the static suction lift plus the velocity head plus the frictional losses. An operating pump located below the supply of fluid must be capable of operating at a total dynamic suction head of the static suction head minus the velocity head minus the frictional losses.

The velocity head is the equivalent height in feet that the fluid would have to fall to equal the fluid velocity produced by the action of the pump. Velocity head is expressed by the equation:

$$h=\frac{v^2}{2g} \qquad 30\text{-}1\text{-}1$$

where:

h = velocity head in feet

v = velocity of fluid flow in feet per second

g = gravitational acceleration (32.2 ft/sec^2)

The maximum dynamic suction lift or the minimum suction head which is required for proper pump operation is termed minimum net positive suction head (MNPSH). When the dynamic absolute pressure at the pump suction is less than MNPSH, vapor cavities occur which is termed cavitation. At any absolute pressure greater than MNPSH, the pump will operate without cavitation. The exact value for MNPSH is dependent on the design of the pump, the type of fluid being pumped, and the temperature of the pumped fluid. MNPSH is described in more detail in Module 30-2 with regard to pump functional testing.

Discharge Head and Total Static Head

If a vertical column were added to the discharge side of a dynamic pump, the fluid would rise to a level designated as the discharge head. For displacement pumps, an equivalent measure of discharge head is in pounds per square inch. The discharge head is measured from the level of the pump and is comprised of a pressure head, velocity head, and elevation head.

The absolute difference between the discharge head and the suction head is the pump head or total head. The total head may be considered in terms of total static head or total dynamic head. Total static head takes into account the difference in fluid level from suction to discharge. Total dynamic head additionally takes into account velocities, fluid density, and frictional losses of a specific pump system. Discharge head and total static head are illustrated in Figures 30-1-5 and 30-1-6.

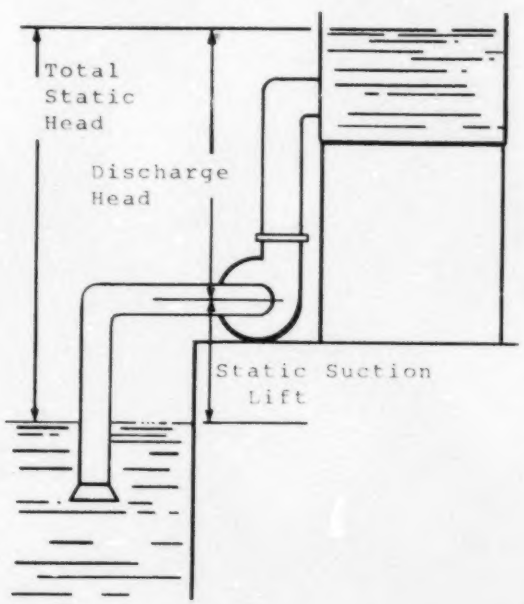

Figure 30-1-5. Discharge Head and Total Static Head with Negative Suction Head

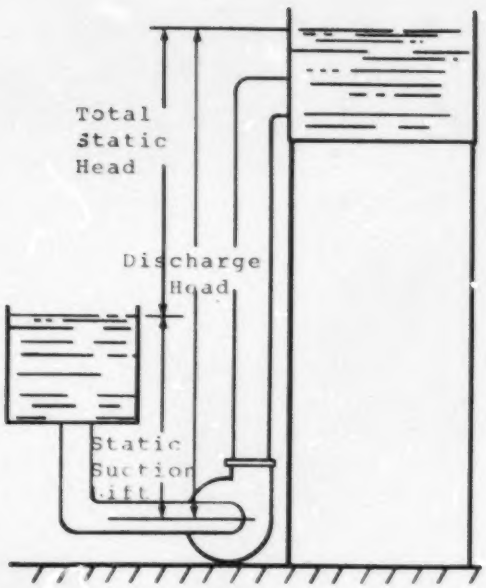

Figure 30-1-6. Discharge Head and Total Static Head with Positive Suction Head

CENTRIFUGAL PUMPS

Principle of Operation

A centrifugal pump imparts centrifugal force to the fluid as illustrated in Figure 30-1-7 to, to induce fluid flow. Centrifugal force acts to move a body away from its axis of rotation when the body is moving in a circular motion. This force gives kinetic energy to the fluid and a portion of the kinetic energy is then converted in the pump to static pressure or pressure head.

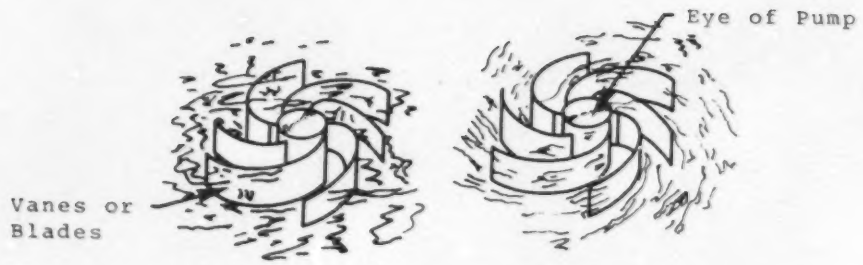

Figure 30-1-7. Simplified Sketch of Centrifugal Action

Volute Centrifugal Pump

The volute centrifugal pump is comprized of an impeller and a casing of unique configuration. When the impeller is rotated, the fluid is slung outward into the space between the impeller and the casing. As illustrated in Figure 30-1-8, the outer edges of the impeller and the inner casing wall form a continuously divergent space. This divergent space, or volute, causes a portion of the kinetic energy of the fluid to be converted to pressure as the velocity of the fluid slows. In Figure 30-1-8, the divergent spacing is continued to the discharge point. Thus, at the exit from the discharge nozzle a velocity head and a pressure head has been imparted by the pump.

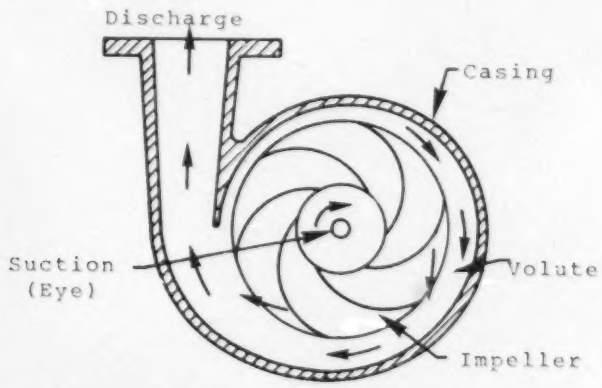

Figure 30-1-8. Volute Type Centrifugal Pump

Diffuser type Centrifugal Pump

Diffuser centrifugal pumps use stationary guide vanes (diffuser) which surround the impeller. As illustrated in Figure 30-1-9, the curvature of the diffuser vanes form a divergent space. This divergent space converts some kinetic energy of the fluid to pressure head in the same manner as the volute. Further conversion of kinetic energy to pressure occurs in the divergent nozzle.

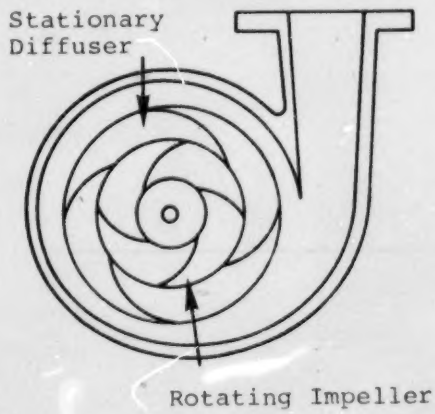

Figure 30-1-9. Diffuser Type Centrifugal Pump

Radial Flow Centrifugal Pumps

Centrifugal pumps are also classified by direction of fluid flow with respect to the impeller. If the pumped fluid flows outward, away from the impeller shaft, the pump is a radial flow pump. The volute pump and the diffuser pump illustrated in Figures 30-1-8 and 30-1-9 are radial flow pumps.

Axial Flow Centrifugal Pumps

If the pumped fluid flows along the axis of the impeller shaft, it is an axial flow pump. The vanes of an axial flow pump are shaped similar to the propeller vanes of an outboard motor. Figure 30-1-10 illustrates a typical

axial flow type centrifugal pump. Axial flow pumps offer higher flow rates at lower pump heads than radial flow pumps.

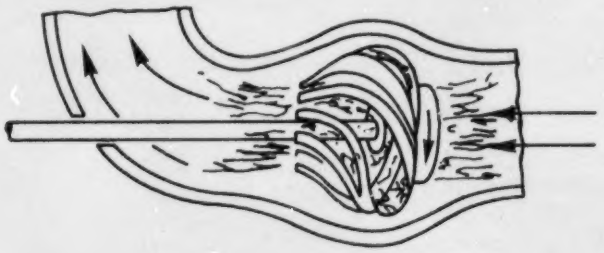

Figure 30-1-10. Axial Flow Centrifugal Pump

Mixed Flow Centrifugal Pumps

A centrifugal pump that combines both radial and axial flow is classified as a mixed flow centrifugal pump. In this type of pump, as shown in Figure 30-1-11, the fluid enters the impeller in the axial direction and discharges in both the axial and radial directions.

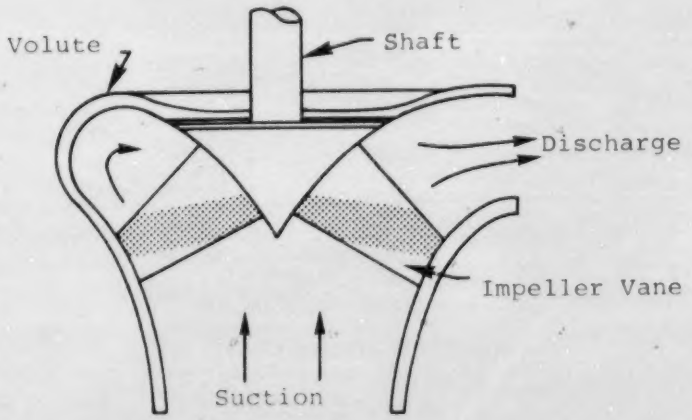

Figure 30-1-11. Mixed Flow Centrifugal Pump

Mixed flow centrifugal pumps are frequently used for circulating water pumps. In this application, the pumps are

installed vertically with the suction submerged in water at all times. Large flow rates at a medium pump head and low rotational speed are provided by mixed flow centrifugal pumps.

Double Suction Centrifugal Pumps

Centrifugal pumps which have two radial flow impellers mounted back-to-back are classified as double flow or double suction centrifugal pumps. In a double suction centrifugal pump, the fluid flows in through two suctions but out a common discharge line. This arrangement offers higher flow capacity with little increase in pump head.

Multi-Stage Centrifugal Pumps

Centrifugal pumps are further classified by number of stages. A stage consists of one combination of suction and discharge. A centrifugal pump with one impeller is a single stage pump. In a multistage centrifugal pump, the first impeller discharges to the suction of the next impeller and so on for as many stages as the pump has. Multistage pumps are used to provide a given flow rate at a higher discharge head.

Shaft Seals

Centrifugal pumps require a seal between the pump shaft and the shaft penetration into the pump casing. Otherwise, serious leakage will occur.

The method of sealing the shaft is dependent on the size of the pump, the pressure of the fluid being pumped, and the temperature of the fluid being pumped. Figure 30-1-12 illustrates the simplest type of pump seal, i.e., the stuffing box. A stuffing box shaft seal is typically used when pumping low pressure fluids The stuffing box consists of an annular space in the pump casing where rings of packing

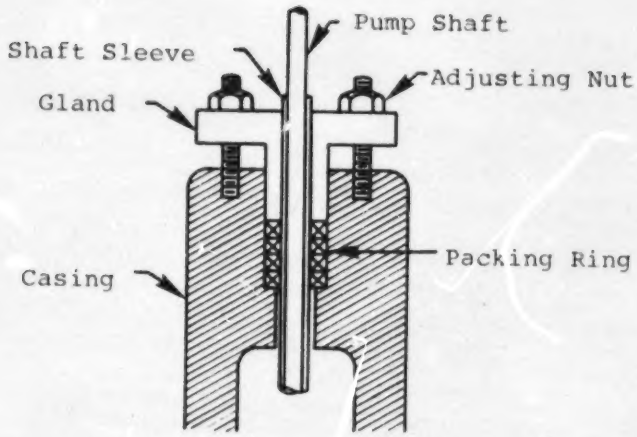

Figure 30-1-12. Stuffing Box Shaft Seal

material are placed. The packing rings are held in place by a packing gland or follower that is bolted to the pump casing. As the adjusting nuts are tightened, the packing gland compresses the packing material radially against the shaft to form a tight seal. The shaft sleeve shown in Figure 30-1-12 provides excess material to permit wear without degrading the strength of the shaft. Cooling and some lubrication of the seal is needed to prevent overheating the packing material. Lubrication and cooling can be provided by loosening the gland slightly to permit a small quantity of fluid to leak along the shaft. Another method is forced lubrication and cooling as illustrated in Figure 30-1-13. Forced cooling is used if the pump suction is under a vacumn such that outward leakage is impossible or when the fluid being pumped is too hot to provide adequate cooling. In this case, a supply of clean, cool water is supplied to the stuffing box to provide adequate cooling and lubrication. This water, called gland cooling or gland sealing water, is injected through a drilled passage in the pump casing to a lantern ring located in the middle of the

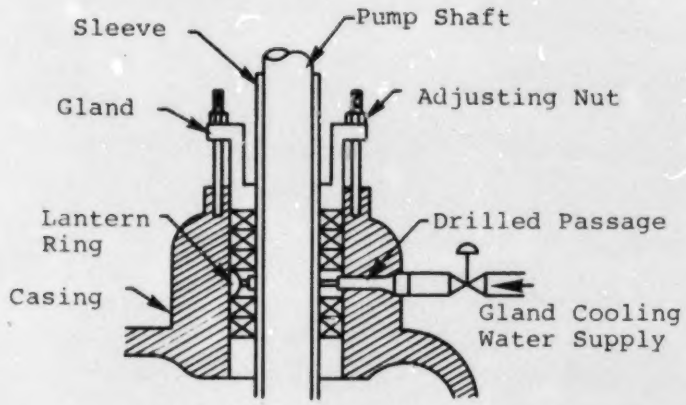

Figure 30-1-13. Water Cooled Shaft Seal

stuffing box. The lantern ring distributes the sealing water around the shaft to provide the required cooling and lubrication.

Packing used for pump shaft seals may be any of the six styles illustrated in Figure 30-1-14. These styles are diagonal braid, twist, plait, laminate, braid, and wrap.

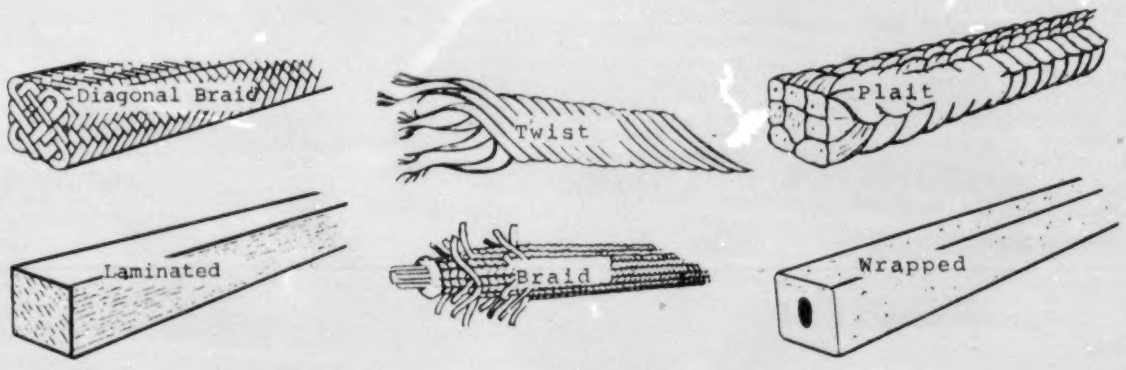

Figure 30-1-14. Styles of Packing

Canned Pumps

Some pumps in nuclear power plants pump fluid that is potentially radioactive. Leakage from these pumps is carefully controlled. One type of pump used in this case is the canned pump which is illustrated in Figure 30-1-15.

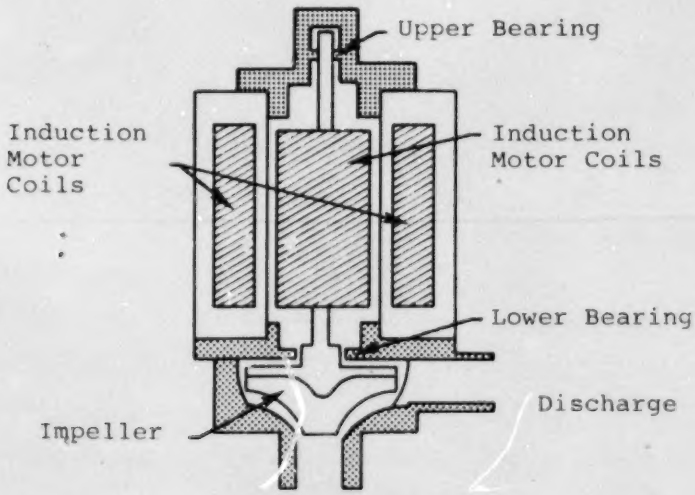

Figure 30-1-15. Canned Pump

In the canned pump, the prime mover is encapsulated (canned) and seal welded to the pump casing. The prime mover (an induction motor) is cooled and lubricated by a portion of the fluid being pumped which is circulated along the shaft and between the rotor and stator cans. This fluid also lubricates the motor bearings.

JET PUMPS

Principle of Operation

Jet pumps are dynamic pumps which do not have moving parts. Instead a high velocity fluid serves as the prime mover. The basic jet pump is illustrated in Figure 30-1-16.

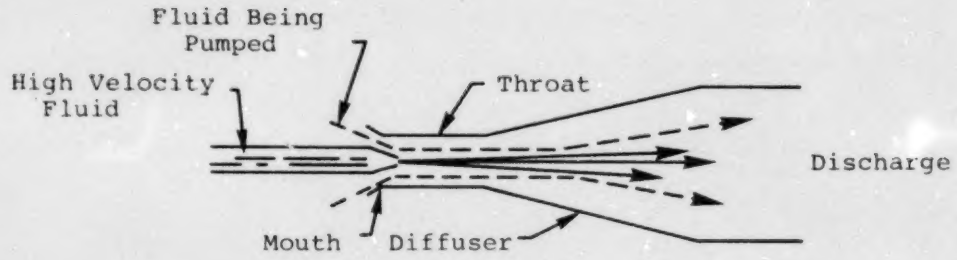

Figure 30-1-16. Jet Pump

Referring to Figure 30-1-16, a high velocity fluid is directed through a nozzle toward a diffuser. The high velocity fluid impinges on the fluid to be pumped and carries it along with the high velocity fluid. This process is termed "entrainment". As the entrained fluid is carried out of the throat of the diffuser, a low pressure area is created around the mouth of the diffuser. This establishes a differential pressure that forces more of the fluid to be pumped into the diffuser where it is entrained, thus continuing the process. The divergent section of the diffuser converts a portion of the kinetic energy to pressure or pump head.

DISPLACEMENT PUMPS

Principle of Operation

Displacement pumps move a specific quantity of fluid with each pumping cycle. These pumps entrap a quantity of fluid at the pump suction and physically move it to the pump discharge. As long as the prime mover operates the displacement pump, fluid is pumped into the discharge regardless of discharge pressure. If the speed of operation of the displacement pump is constant, the fluid flow rate is consatnt regardless of discharge pressure. Two types of

displacement pumps are common: the reciprocating positive displacement pump and the rotary positive displacement pump.

Reciprocating Positive Displacement Pump

A simplified sketch of the reciprocating positive displacement pump is provided by Figure 30-1-17.

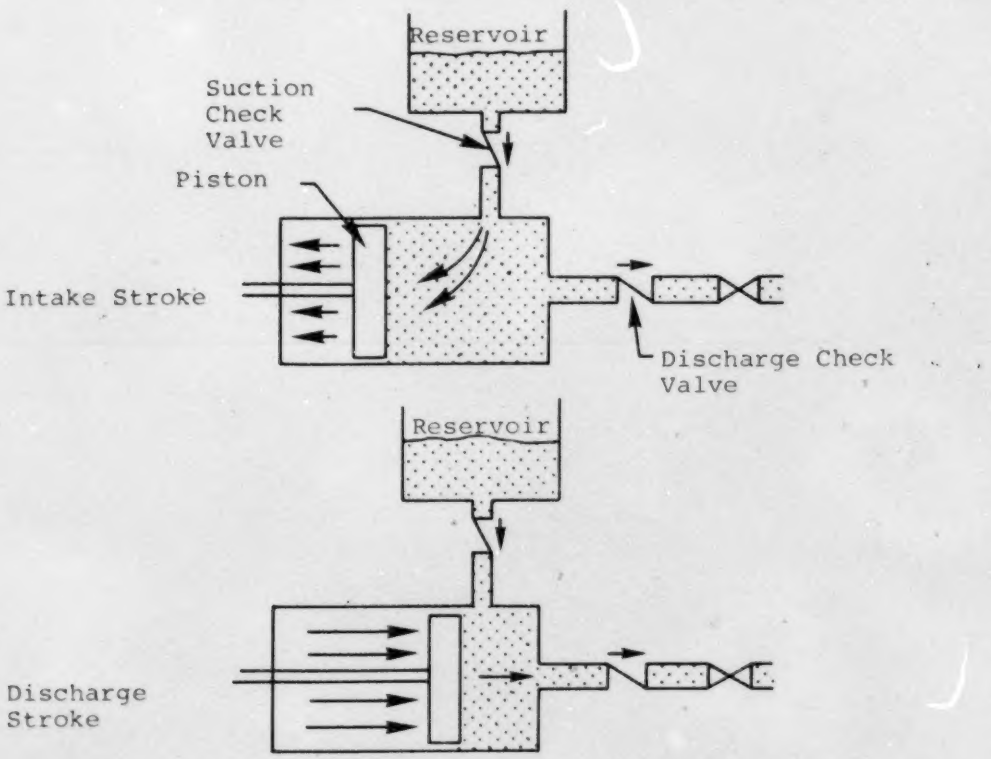

Figure 30-1-17. Reciprocating Positive Displacement Pump

As illustrated in Figure 30-1-17, the intake stroke occurs as the piston moves to the left. During the intake stroke, the suction line check valve opens allowing fluid to enter the cylinder. As the piston moves to the right, in Figure 30-1-17, the suction check valve is forced closed and the

discharge check valve is forced open by the displacement of the fluid. The piston physically pushes the fluid into the discharge. This type of positive displacement pump is known as single-acting because the fluid is forced into the discharge piping only with one motion of the piston and not on the other motion of the piston. Reciprocating pumps are also designed to have suction and discharge valves which allow pump discharge on both motions of the piston. Such pumps are double-acting positive displacement pumps.

Rotary Positive Displacement Pump

A second type of positive displacement pump is the rotary pump. The rotor may be lobes or gears. Figure 30-1-18 illustrates a typical rotary gear pump.

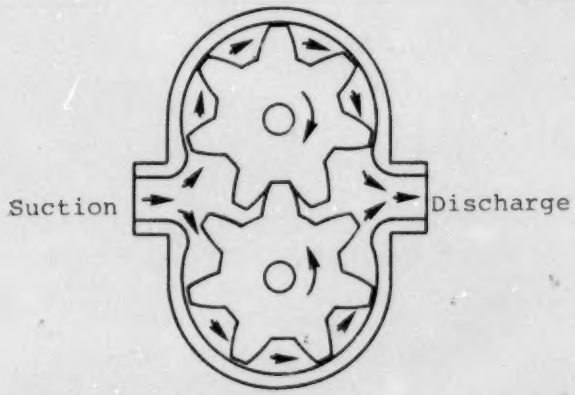

Figure 30-1-18. Rotary Gear Pump

In the gear pump, the fluid being pumped is trapped between the gear teeth and the pump casing. As the gears rotate, the fluid is physically carried around to the pump discharge. The discharge fluid flow is much less pulsating than with a reciprocating pump and may be considered as smooth, constant flow.

PUMP INSPECTION SPECIFICATIONS

Pump Design Specification

The nuclear power plant owner, or a contractor thereto, develops a design specification for each type of pump to be used in the nuclear plant. The design specification stipulates the type of pump and all its design features. It is applied to the manufacturer of the pump who must deliver pumps which meet the requirements of the design specification.

Inspection activities of the owner use the requirements of the pump design specification, including engineering drawings which are referenced thereby, as the acceptance criteria for inspections at the manufacturer's plant or at receipt of the delivered pump. The owner's quality control department may directly perform the inspections or the owner may contract for inspection services. In either case, inspections are planned and conducted to confirm that delivered pumps conform with the pump design specification.

System Design Specification

The nuclear power plant owner, or a contractor thereto, develops a design specification for each system of the plant. The system design specification stipulates the types of components which will comprise the system, criteria to be met while installing the system, and system functions and limits during normal, shutdown, and emergency condition of operation.

Inspection activities of the owner use the requirements of the system design specification and pump design specification as acceptance criteria for inspections during installation, preoperational testing, and operational activities. The owner's quality control department or a

contractor may perform the inspections. In either case, inspections are planned and conducted to confirm that pumps are installed, tested, and operated in accordance with the system and pump design specifications.

Quality Assurance Standard

Quality assurance requirements for installation, inspection and testing of pumps are specified by an American National Standard. This standard is ANSI N45.2.8, "Supplementary Quality Assurance Requirements for Installation, Inspection, and Testing of Mechanical Equipment and Systems for the Construction Phase of Nuclear Power Plants". While the title of this standard indicates it is applicable to construction, it provisions are also used, as applicable, in the operations phase of the plant.

ANSI N45.2.8 requires the planning for and implementation of inspections of pumps during three major evolutions. These evolutions are (1) preinstallation verifications, (2) control of installation process, and (3) installed system inspections and tests.

PREINSTALLATION INSPECTION

Purpose and Scope

Preinstallation inspections of pumps verify that the pump and the installation area comply with specified requirements. When a pump is received at the nuclear power plant site, it is receipt inspected for conformance with the pump design specification. Accepted pumps are tagged with an acceptance tag and placed in storage until it is needed for installation. Preinstallation inspection confirms that the identity and condition of the pump is maintained. Installation areas are inspected to confirm that procedures, trained personnel, and installation equipment are available as required by the system design specification and installation drawings. These installation inspections are applied to (1) identification, (2) processes and procedures, (3) pump physical conditions, and (4) site conditions.

Identification Inspections

The installation contractor must establish a quality assurance program which ensures items are properly installed into their correct location or specified by installation drawings. The quality assurance program provides for maintaining lists or procedures which designate the exact components to be installed in a given system. At release of a pump from storage to the installation area, the inspection activity confirms that the designated pump is in fact released.

Pump identification is provided by the name plate and the accept tag. The data on the name plates are verified as correct by receiving inspection and thereafter the name plate is used as acceptable indication of pump identity. The pump design specification stipulates what is required on the name plate. It typically requires (1) name of system for which the pump is intended, (2) pump manufacturer's

name, (3) type of pump, (4) size of pump, (5) flow capacity, (6) pump head rating, and (7) serial number of the pump. An example name plate is illustrated in Figure 30-1-19.

Ingersoll Rand			
System:	Core Spray	Type:	Centrifugal
Size:	10 x 14	Flow:	3400 gpm
Serial:	365-187	Head:	450 feet

Figure 30-1-19. Sample Name Plate Data

Preinstallation inspectors compare name plate data and the accept tag data with the installation procedures to confirm that the correct pump is released for installation. Also, a roving inspector is typically assigned to periodically check released pumps to confirm that their identity is maintained.

Inspection of Processes and Procedures

Installation procedures and drawings are prepared for use by the installation contractor. For a given installation activity, the procedures and drawings applicable to that activity are collectively termed "job package". The job package may be attached to the component at release from storage or it may be issued to the supervisor of the installation group. The job package delineates all necessary instructions for installing an item such as a pump.

Preinstallation inspectors confirm that a complete job package is on hand and that its provisions are met. This inspection may be on a roving basis such that an inspector proceeds from one installation activity to another as checks are completed. Checks are typically made to verify (1) availability of approved procedures and drawings, (2) qualification of personnel as required, (3)

compliance with prerequisites, (4) availability of necessary handling and fixturing devices, and (5) compliance with safety requirements.

- Approved procedures and drawings - In addition to to confirming that the correct job package is available, the inspector checks for other procedures which are required by the installation procedure or drawing. Such other procedures typically involve special processes which will be required for the installation work. Examples include welding procedures, cleaning procedures, heat treating procedures, and coating procedures.
- Qualification of personnel - The inspector confirms that persons assigned to the installation are qualified if formal qualification is required. Welders and nondestructive examination personnel are required to be qualified. Dimensional and visual inspectors may also be required to be qualified.
- Compliance with prerequisites - The installation procedure specifies any prerequisites which must be met prior to installing a pump. Examples include removal of packing and plugs which protected the pump internals, removal of protective coatings, and cleaning the general area.
- Handling and fixturing - Dependent on the type and size of pump, various handling equipment and fixtures are necessary for safe movement and positioning of the pump. The inspector verifies availability of such equipment as specified by the job package.
- Safety - The inspector verifies compliance with safety precautions stipulated by the job package. For pump installation, the safety requirements are typically those associated with routine installation activities such as use of hard hats and eye protection.

Inspection of Pump Physical Conditions

During the inspection of installation processes and procedures, the inspector also checks the physical conditions of the pump. These checks insure that (1) the quality of the pump has been maintained, (2) any prior reported non-conformances have been corrected, and (3) the pump is adequately clean for installation.

Checks on maintenance of pump quality look for physical damage from mishandling and for unique conditions applicable to the pump. Examples of unique conditions are:

- Weld and preparations are undamaged for pumps which will join suction or discharge piping by welding.
- Excessive rusting has not occurred.
- Inert gas blankets, when required for canned pumps, have been maintained.
- Protective caps and plugs are kept in place until installation begins.

Inspection of Site Conditions

During the inspection of installation processes and procedures, the inspector also checks site conditions for compliance with the requirements of the job package. These checks verify that site conditions have been established as required to avoid adversely affecting the quality of the pump. Examples include:

- Protection from adjacent installation activities such that there is little risk of damage to the pump.
- Protection from inclement weather such as snow, rain, sleet, etc.
- Installation of permanent or approved temporary supports on which the pump will be mounted.
- Required maintenance of the pump has been performed, such as checking lube oil level in a reciprocating pump.

INSTALLATION INSPECTION

Purpose and Scope

While reinstallation inspections verify readiness to proceed with installation, installation inspections verify that required quality is obtained by the installation work. To accomplish this purpose, critical steps in the installation process are selected for inspection and other installation steps are inspected on a roving basis. These inspections encompass (1) control of procedures and processes, (2) nondestructive examinations, (3) work in progress, and (4) final installation.

Control of Procedures and Processes

Inspections on the control of procedures and processes verify that established controls are being implemented throughout the installation time cycle. These inspections are typically performed on a roving basis and check for procedural compliance by the various steps of installation work. These inspections typically check for (1) control of revisions to procedures and drawings, (2) use of approved procedures and materials by qualified personnel, (3) indication of quality status, (4) compliance with sequence, (5) control of nonconformances, (6) recording as-builts, and (7) completeness of inspections and tests:

- Control of revisions to procedures and drawings - drawings contained or referenced by the job package may require revision for a number of reasons. Whenever a job package has been released to the installation contractor, any subsequent revision to applicable procedures or drawings must result in providing to the installation contractor the revised document. Installation inspections confirm that the latest approved revision levels of procedures and drawings are in use by the installation contractor.
- Use of qualified personnel, procedures, and materials -

Installation inspections confirm that personnel actually performing the work are qualified as required, that procedures in use are qualified or approved, and that materials being used are those specified by the procedures and drawings. Examples of materials include threaded fasteners, welding materials, shims, and shaft packing.

- Indication of quality status - As installation proceeds, the status of installation including inspections and tests must be clearly identifiable. Such indication of status may be provided by inspection reports, tagging the pump, or signoff of installation check lists. The installation inspector confirms that indication of quality status is maintained.
- Compliance with sequence - The job package includes the sequence of steps for proper installation, inspection and test of pumps. The installation inspector verifies compliance with the specified sequence.
- Control of nonconformances - Inspections and tests required by the job package may identify nonconforming conditions. In such cases, the pump is tagged as nonconforming and a nonconformance report is initiated. Engineering determines what correction of the nonconformance is necessary and issues appropriate instructions. Until completion of the correction, the pump status must be maintained as nonconforming. The installation inspector verifies the tagging of nonconforming pumps and maintenance of such tagging until the nonconformance is corrected.
- Recording of as-builts - The job package may require that certain dimensions be recorded to reflect the as-built values of the installed pump. For example, the actual, installed location of the pump discharge

nozzle with respect to a datum may be needed to permit fabrication of a piping assembly which will eventually connect to the pump discharge. The installation inspector verifies that required as-built information is recorded as installation progresses.

- Completeness of inspection and test - The job package stipulates the inspections and tests to be performed during the installation process. The installation inspector verifies that inspection and test reports are prepared for each required inspector and test.

Nondestructive Examinations

Nondestructive examinations of pump installations are typically required only for welded joints such as welds between suction and discharge piping and the pump. Because many pumps have bolted flange connections to piping as well as bolted support mounts, nondestructive examinations may consist of liquid penetrant, magnetic particle, radiography or ultrasonic tests. For weld joints in magnetic materials, magnetic particle and radiography are typically required. For weld joints in nonmagnetic materials, liquid penetrant and radiography are typically required. For welds which are subject to later inservice inspection by ultrasonic testing, an ultrasonic test is performed at installation to establish a known "base-line" for comparison with later inservice ultrasonic tests. Whenever nondestructive testing is required, it must be performed to an approved procedure by qualified persons.

Work in Progress

Installation inspections are planned for work in progress to ensure that critical installation requirements are

met. For critical requirements, inspection hold joints are established which require installation work to stop at such points until the inspection is performed. For installation work steps considered not critical, a roving inspector periodically checks for compliance with the job package. Typical hold points for pumps include:

- Orientation - Inspection verifies that the pump is mounted with suction, discharge, and prime mover connections in the correct orientation.
- Levelling and alignment - Inspection verifies that requirements for levelling and alignment are met. The alignment between the prime mover and the pump shaft is of particular importance.
- Torquing of threaded fasteners - Bolted mounts, pipe-to-pump flanges, and pipe hangers are torqued to specified values. The installation inspector typically witnesses torquing of threaded fasteners.
- Shaft seals or packing - For pumps having mechanical seals, the installation inspector witnesses the installation and adjustment of the seals. For pumps having flexible peaking, pump manufacturer typically installs the packing but does not fully compress it. The installation inspector witnesses the tightening of compressible shaft packing to verify torquing to a specified value.
- Fluid levels - The prime mover may contain reservoirs for lubricating oils or may require certain lubrication at installation. The installation inspector checks for compliance with specified requirements for lubrication and any other maintenance item which may be required.

The remainder of installation work is typically checked by a roving installation inspector. Such addition work activities include cleaning, welding, pipe fitting, house-

keeping, and protection of pump intervals from foreign materials.

Final Installation Inspection

Once the pump is installed, the installation inspector makes a final inspection which serves to report the acceptance of the installation. The final inspection verifies that:

- All steps of the job package have been completed including all inspections and tests and correction of any nonconformances.
- External connections have been completed including piping, cooling water, lubrication lines, and power connections as required.
- Prime mover rotation is correct.
- Limit switches, interlocks, and stops are installed.
- All designated mounts, hangers, and supports are installed.
- All designated temporary protective plugs, covers, and strainers are in place.

At this point, installation inspection has verified that the correct pump has been properly installed in the right location. The pump is now ready for preoperational tests. However, the entire system which contains the pump must typically be installed prior to conducting preoperational tests.

PREOPERATIONAL TESTS

Types

Preoperational tests for pumps basically consist of either integrity tests or functional tests. Integrity tests are those which check the physical condition of the pump. Functional tests are those which check the operating performance of the pump. Integrity tests for pumps consist

of hydrostatic testing and seal leakage testing. Functional tests are described in Module 30-2 of the Mechanical Inspection Course.

Hydrostatic and Seal Leakage Testing

Hydrostatic and seal leakage tests are typically performed as one integrated test. The pump may be tested as an individual component but most often is tested in conjunction with testing the system which employs the pump. Detailed test procedures are used for conducting these tests.

Prior to conducting integrity tests, established prerequisites must be met. These prerequisites typically include flushing the system to achieve the specified level of cleanliness and removing or installing temporary protective devices such as plugs, blanks, and screens.

Hydrostatic testing requires the filling of the pump with water and pressurizing the water to a specified value. Specified test pressures are typically 120% of design pressure of the pressure boundary parts. With the pump filled and pressurized to test pressure, an inspector visually checks for evidence of leaks. Acceptance criteria is typically no evidence of leaks other than design leakage along the pump shaft. Leaking connections are retorqued or replaced as necessary to eliminate leaks.

Shaft seal leakage tests typically immediately follow the visual inspection of the hydrostatic test. With the pump still at test pressure, shaft seal leakage is measured. Measurement of shaft seal leakage typically involves the use of a coffer dam around the shaft and plastic tubing to drain the leakage. The leakage is collected for a timed interval in a graduated beaker. Leak rate is calculated by dividing the volume collected by the collection time. Leak rate is normally in units of cubic centimeters per hour. Where limits on shaft seal leak rate are

exceeded, the seal is either adjusted or replaced to bring the leak rate within limits.

EXERCISES

The following exercises serve to reinforce the information presented in this module.

A. Perform the following exercises on Fundamental Pump Design, Centrifugal Pumps, Jet Pumps and Displacement Pumps presented in this module. Answers to these exercises are presented at the end of this section.

1. What are the two classifications of pumps based on the principles of adding energy to the pump fluid?
   a.
   b.

2. Define:
   a. Static suction lift

   b. Static suction head

   c. Discharge head

   d. Total static head

3. Briefly describe the principle of operation of:
   a. single stage, radial flow, centrifugal pump

   b. jet pump

   c. single acting reciprocating displacement pump

4. Describe the centrifugal pump classifications of:
   a. radial flow

   b. axial flow

   c. mixed flow

   d. multi-state

   e. canned

5. Describe two methods of lubricating and cooling compressible shaft seals for centrifugal pumps.
   a.

   b.

6. Briefly describe the operation of a rotary gear pump.

7. Describe how pump suction and discharge pressure units in feet, give a meaningful measurement.

Check your answers to the Part A Exercises on Fundamental Pump Designs, Centrifugal pumps, Jet Pumps and Displacement Pumps as follows:

1. a. Dynamic
   b. Displacement

2. a. Static suction lift is the vertical distance in feet from the level of the fluid supply below the pump to the axis of the pump.
   b. Static suction head is the vertical distance in feet from the level of fluid supply above the pump to the axis of the pump.
   c. Discharge head in the vertical distance in feet above the axis of the pump to which the discharge fluid would rise in a free-standing column.
   d. Total static head is the absolute difference between discharge head and suction head, or, it is the vertical distance in feet between the levels of fluid from discharge to suction.
3. a. The single stage, axial flow centrifugal pump adds kinetic energy to the fluid by centrifugal action caused by impeller rotation. A portion of the kinetic energy is converted to pressure in the divergent volute.
   b. The jet pump uses a high velocity fluid to impinge on the fluid to be pumped. The entrained fluid creates a low pressure point which permits more fluid to be entrained. A portion of the entrained fluid's kinetic energy is converted to pressure in a divergent discharge nozzle.
   c. A single acting reciprocating displacement pump pulls fluid into a cylinder on the intake stroke and physically forces fluid out the discharge on the discharge stroke. Check valves are arranged to permit fluid flow only in the desired direction during each stroke.
4. a. Radial flow is a classification of centrifugal pump where the pumped fluid flows radially outward from the impeller shaft.

b. Axial flow is a classification of centrifugal pump where the pumped fluid flows along the axis of the impeller shaft.

c. Mixed flow is a classification of centrifugal pump where the pumped fluid flows both radially and axially with respect to the impeller shaft.

d. Multi-stage centrifugal pumps are two or more impellers where the first impeller discharges to the suction of the next impeller and so on for the number of impellers included.

e. Canned centrifugal pumps have the prime mover sealed to the pump such that leakage along the impeller shaft cannot escape from the cans to the surroundings.

5. Two methods of cooling and lubricating compressible shaft packing are:
   a. shaft leakage of the fluid being pumped
   b. an external supply of water to the seal.

6. The rotary gear pump physically entraps fluid between gear teeth and the pump casing. As the gears rotate, fluid is carried around the inside of the casing to the discharge outlet.

7. Pump pressure units in feet is meaningful because of the direct correlation between level of fluid in feet and the pressure exerted by such level caused by gravitational acceleration on that fluid.

B. Perform the following exercises on Preinstallation, Installation and Preoperational Inspection as follows:

1. What is the purpose of preinstallation inspections?

2. Briefly describe the preinstallation inspections associated with:
   a. identification

   b. processes and procedures

   c. pump physical conditions

   d. site conditions

3. What is the purpose of installation inspections.

4. Briefly describe the installation inspections associated with:
   a. control of procedures and processes

   b. nondestructive examinations

c. work in progress

d. final installation

5. Name two preoperational tests for physical integrity of a pump.
   a.
   b.

6. Describe how to conduct a shaft seal leakage test.

7. Name five data items typically required to be on pump nameplates.

Check your answers to the Part B Exercises on Preinstallation, Installation, and Preoperational Inspections as follows:

1. The purpose of preinstallation inspections is to verify that the pump and the installation area comply with specified requirements.
2. a. Identification inspections check name plate data and presence of an accept tag to ensure that the pump released for installation is the correct pump and was accepted by receipt inspection.
   b. Process and procedures inspections verify availability of approved drawings and procedures, qulaification of personnel, compliance with prerequisites for installation, availability of

handling equipment and fixturing, and compliance with safety requirements.

c. Inspections of pump physical conditions verify that the quality of the pump is maintained, prior reported nonconformances are corrected, and the pump is adequately clean.

d. Inspection of site conditions verify that site conditions are established such that the quality of the pump is not adversely affected. Checks are made on adjacent work activities, protection from inclement weather, installation of mounts, and performance of maintenance.

3. The purpose of installation inspection is to verify that required quality is obtained by the installation work.

4. a. Inspection of the control of procedures and processes verify the control of revisions to procedures and drawings, use of approved procedures and materials by qualified personnel, identification of quality status, compliance with sequence, control of nonconformances, recording of as-builts, and completeness of inspections and tests.

b. Nondestructive examinations are inspections of welded joints for the purpose of determining acceptance of the weld and establishing base line data for later inservice inspections.

c. Inspections of work in progress are comprised of hold points and random inspections. Inspections at hold points include checks for orientation, levelling and alignment, torquing, shaft sealing, and fluid levels. Random inspections periodically check for compliance with the remainder of installation work such as welding, cleaning, fitting, housekeeping, and physical protection of pump inter-

nals.

d. Final installation inspection verifies that all steps of the job package have been successfully completed, external connections have been made to the pump, prime mover rotation is correct, limit switches and interlocks have been installed, and mounts, hangers, and supports have been installed.

5. Two preoperational physical integrity tests are hydrostatic tests and shaft seal leakage tests.

6. A shaft seal leakage test is conducted with the pump pressurized with water to a specified value. The leakage along the shaft is collected and measured for a timed interval. Dividing the volume collected by the time interval gives the leak rate.

7. Pump name plates typically give:
   a. manufacturer's name
   b. type of pump
   c. size of pump
   d. flow capacity
   e. pump head
   f. name of system receiving the pump
   g. serial number.

MATERIALS

There are no required materials for this module.

PROCEDURES

There are no required procedures for this module.

DATA TABLE

There are no required data tables for this module.

REFERENCE MATERIALS

ASME, ANSI N45.2.8, Supplementary Quality Assurance Requirements for Installation, Inspection, and Testing of Mechanical Equipment and Systems for the Construction Phase of Nuclear Power Plants, The American Society of Mechanical Engineers, New York, N.Y., 1975

ASME, Boiler and Pressure Vessel Code, Section III, The American Society of Mechanical Engineers, New York, N.Y., 1978

Krutzsch, William C., Pump Handbook, McGraw Hill, 1976

TEST

A. Answer the following questions as being either True or False:

____ 1. Two major classifications of pumps by principal of adding energy to the fluid are dynamic and displacement.

____ 2. Dynamic pumps include positive displacement pumps and jet pumps.

____ 3. Centrifugal pumps add kinetic energy to the fluid by the rotation of an impeller and convert a portion of the kinetic energy to pressure in the volute.

____ 4. Jet pumps may be of axial flow, radial flow or mixed flow subclassifications.

____ 5. Centrifugal pumps may be single stage, multi-state or double suction.

____ 6. Jet pumps use the kinetic energy of a high velocity fluid to entrain the fluid to be pumped. Entrainment creates a lower pressure which promotes fluid flow. A portion of the kinetic energy is converted to pressure in the divergent nozzle discharge section of the jet pump.

____ 7. Displacement pumps include reciprocating and rotary positive displacement pumps.

____ 8. The advantage of a positive displacement pump is that it is designed to pump both water and steam.

____ 9. Displacement pumps physically carry a quantity of fluid from suction to discharge.

____ 10. Reciprocating positive displacement pumps may be single acting, double acting, or reverse flow types.

____ 11. Rotary positive displacement pumps may be gear or lobe types.

____ 12. Static suction head is the vertical distance in feet from the level of the fluid supply to the axis of the pump. When the level of supply is below the pump, the term is usually referred to as static suction lift.

____ 13. Discharge head is the vertical distance in feet from the pump axis to the sea level elevation.

____ 14. Total static head is the absolute difference between discharge head and suction head, or, the vertical distance in feet from the level of discharge fluid to the level of suction fluid.

____ 15. The principle specifications which provide acceptance criteria for pump inoperation are the pump design specification and the system design specification, including associated design and installation drawings.

____ 16. Quality assurance provisions for pump installation, inspection and testing are given by the American Pump Installation Society Procedure N45.2.8.

____ 17. Preinstallation inspections verify that the pump and the installation area comply with specified requirements.

____ 18. Preinstallation inspections are applied to pump identification, processes and procedures, pump physical condition, and site condition.

____ 19. Installation inspections encompass control of procedures and processes, nondestructive examinations, work in progress, and final installation.

____ 20. Preoperational integrity tests are hydrostatic and shaft seal leakage tests.

B. Answer the following questions.

1. Define or briefly explain the following terms:
   a. Static suction lift
   b. Discharge head
   c. Radial flow
   d. Centrifugal pump
   e. Mixed flow
   f. Velocity head
   g. Cavitation
   h. Minimum net positive suction head (MNPSH)
   i. Volute
   j. Shaft seals
   k. Entrainment

2. Match the following specifications listed in the left-hand column with the purpose given in the right-hand column.

Specification	Purpose
___ 1. Pump Design Specification	a. Provides quality assurance requirements for the installation, and testing of pumps.
___ 2. System Design Specification	b. Provides guidelines to the owner for selecting the types of pumps for use.
___ 3. ANSI N45.2.8	c. Provides criteria which must be met by the manufacturer of the pump.
	d. Stipulates the components and functions of a system and the criteria to be met during installation of the system.

3. What is the purpose of preinstallation inspections?

4. Briefly describe the preinstallation inspections associated with:
   a. identification

   b. processes and procedures

   c. pump physical conditions

   d. site conditions

5. What is the purpose of installation inspections.

6. Briefly describe the installation inspections associated with:
   a. control of procedures and processes

   b. nondestructive examinations

   c. work in progress

   d. final installation

7. Name five data items typically required to be on pump nameplates.